Nuclear Energy

Just the Facts

Nuclear Energy—Just the Facts

This booklet explains today's nuclear energy technology, the processes and safety practices associated with it, and the benefits it provides. It includes information about how nuclear power plants work, the cost of producing electricity, nuclear energy's environmental benefits, the mining and production of uranium fuel, the safe management of used nuclear fuel, nuclear plant security, and the economics of nuclear energy. Most of all, it provides "just the facts" for a quick study about nuclear energy.

To learn about nuclear energy at a glance and the contents of this book, simply turn the page.

More detailed information on nuclear energy is available at ***www.nei.org.***

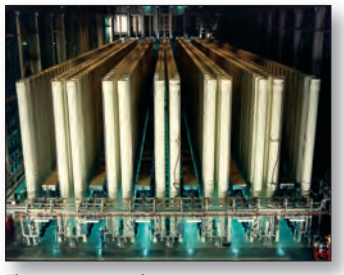
Just the Facts

Nuclear Energy at a Glance

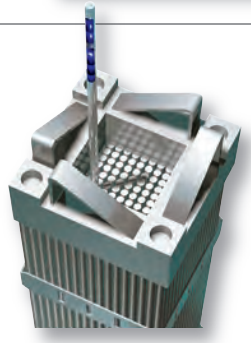
FACT:

The U.S. Nuclear Regulatory Commission strictly **regulates** the commercial and institutional uses of nuclear energy, including nuclear power plants. Quality construction, continuous preventive maintenance and ongoing reactor operator training have contributed to the nuclear energy industry's excellent **safety record**.

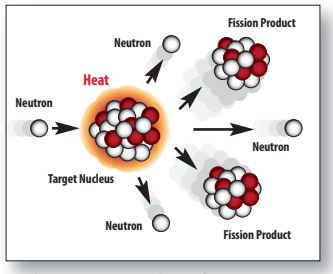
After mining, uranium is milled and processed to create **uranium oxide** or **yellowcake**. *(Page 6)*



The conversion plant removes impurities and chemically converts the material. **Enrichment** makes the uranium usable as a fuel. *(Pages 6 and 7)*

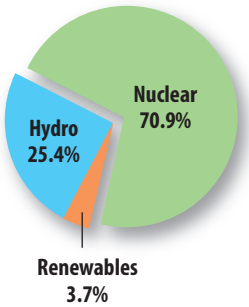


A fuel fabricator presses the uranium into solid, ceramic **pellets** and inserts them into rods making a **fuel assembly**. Assemblies are then transported to the nuclear plant and loaded into the **reactor**. *(Pages 6 and 7)*



In the reactor, **nuclear fission** produces energy to heat water and create steam that powers generators to produce electricity. *(Pages 4 and 5)*

Emission-Free Power



Nuclear energy is by far the largest source of **carbon-free** generation and provides 20 percent of U.S. electricity. By using nuclear power instead of fossil fuel-based plants, the industry prevents the emission of millions of tons of carbon dioxide and other greenhouse gases every year. *(Pages 2 and 3)*

Fuel Pellet (Actual Size)

FACT:

Because nuclear plants do not produce greenhouse gases, the amount of carbon emissions they prevent is larger than all other electricity sources combined. Also, public support for nuclear energy has increased over the past two decades.

A nuclear reactor generates reliable electricity around the clock without producing **greenhouse gases**. *(Pages 2 and 3)*

Building new nuclear plants is critical to meeting U.S. **environmental and energy** goals. *(Page 14)*

With 400 to 700 permanent jobs at a nuclear power plant, it provides significant **economic benefits** to local communities. *(Pages 16 and 17)*

After a cooling period, nuclear power plants store used fuel **safely** and **securely** on site in steel and concrete vaults. *(Page 8)*

Used fuel containers will travel by **trains, trucks** and **barges** to a permanent repository or a recycling facility. *(Page 9)*

Development of advanced **fuel-cycle technologies** improves efficiency and reduces waste but does not preclude the need for a federal repository. *(Pages 10 and 11)*

A deep geologic repository is considered the best method of managing used nuclear fuel and recycling byproducts. The U.S. government is developing a repository at Yucca Mountain, Nev. *(Pages 10 and 11)*

Nuclear Energy in the United States

Just the Facts

- **Electricity is essential** to the everyday lives of Americans and to the nation's economy.
- Nuclear energy generates **20 percent of U.S. electricity**.
- Nuclear power plants produce **clean, reliable and affordable** electricity.

Electricity is vital to everyday life—powering everything from computers to air conditioners, lighting homes, running factories and powering server farms. Electricity generation and distribution are among the greatest achievements of the past century. With affordable power available to all, electricity fuels America's economy and has transformed the way we live and work.

Nuclear energy produces electricity for one in five homes and businesses across the United States, with 104 reactors in 31 states. The country's largest source of carbon-free electricity is nuclear energy, accounting for 70 percent of all emission-free electricity generated. America's reactors operate around the clock, thereby stabilizing the entire country's electricity distribution system and electricity marketplace.

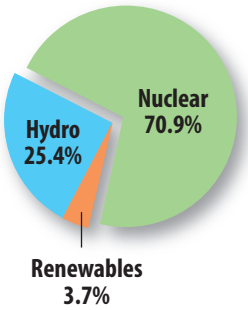
104 Reactors in 31 States

Nuclear Energy Benefits the Environment

FACT:

Nuclear power plants help mitigate climate change because they don't produce greenhouse gases while generating electricity.

U.S. Emission-Free Electricity Sources



Source: Global Energy Decisions/ Energy Information Administration

About one-third of U.S. electricity comes from emission-free sources.

The United States generates most of its electricity by burning fossil fuels, a process that produces sulfur dioxide, nitrogen oxides and **carbon dioxide**. Emission-free sources provide only 30 percent of America's electricity, and 70 percent of that comes from nuclear power plants.

Nuclear power plants don't burn anything.

Nuclear power plants don't burn anything, so they produce no combustion byproducts. Nuclear plants help protect our air quality and have been an important tool in meeting **Clean Air Act** goals in many states. Coupled with renewable energy options, nuclear energy is critical to meeting the country's environmental and energy goals.

The United States needs abundant electricity and clean air.

Given the country's growing demand for new sources of electricity—as much as 25 percent by 2030, according to the Energy Information Administration's 2008 forecast—the United States will need all **new sources of generation** available: renewables, coal, natural gas and nuclear energy. Nuclear energy is the only large-scale, emission-free energy source that can be widely expanded.

Environmental monitoring programs are a hallmark of the nuclear industry.

Endangered species find sanctuaries at nuclear power plants.

Nuclear power plants are so clean and safe that they provide excellent habitat for wildlife and plants. Some nuclear energy companies have developed environmentally rich wetlands, providing better nesting areas for waterfowl and other birds, new habitats for fish, and sanctuaries for other wildlife, flowers and grasses. "Residents" at nuclear power plant sites include many endangered and protected species, such as the American crocodile, manatee and shortnose sturgeon.

Nuclear power plants have won praise for their environmental activities.

Environmental programs conducted by companies operating nuclear plants have been recognized by the nation's best-known **environmental organizations**, including the Audubon Society, Ducks Unlimited, the National Wildlife Federation, the Nature Conservancy, Trout Unlimited, the Wildlife Habitat Council, and the U.S. Fish and Wildlife Service.

The resourceful and adaptive coyote prefers the protected habitat of the Palo Verde nuclear plant site in Arizona.

Emissions prevented by nuclear power plants nearly equal those produced by all U.S. passenger cars.

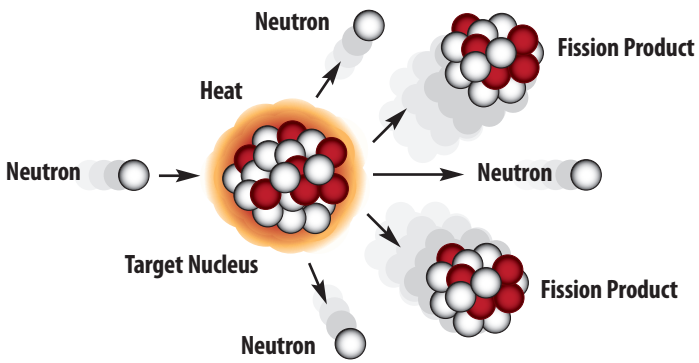
By using nuclear power instead of fossil fuel-based plants, the U.S. nuclear energy industry prevents millions of tons of carbon dioxide emissions every year. The volume of **greenhouse gas emissions** prevented at the nation's 104 nuclear power plants is equivalent to taking nearly **all passenger cars** off America's roadways.

Many endangered and protected species, such as the shortnose sturgeon, find sanctuaries at nuclear plant sites.

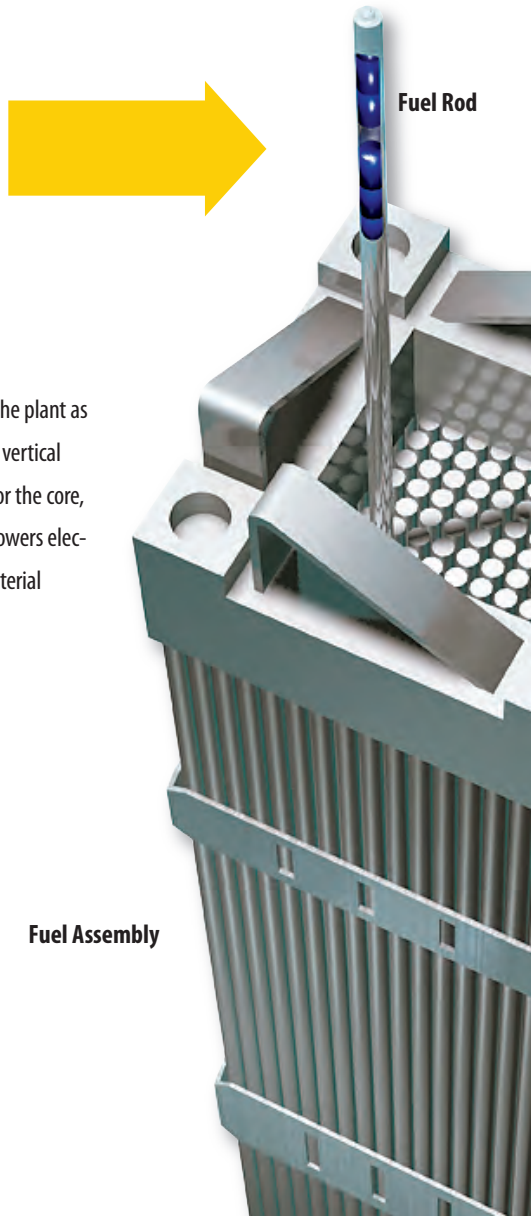
How Nuclear Power Plants Work

FACT:

A nuclear plant produces steam using the heat produced by splitting atoms in uranium fuel. This steam drives a turbine to produce electricity.



*Instead of coal, oil or natural gas, nuclear reactors use enriched uranium for fuel. Uranium atoms make heat by **splitting**—the technical term is **fissioning**.*

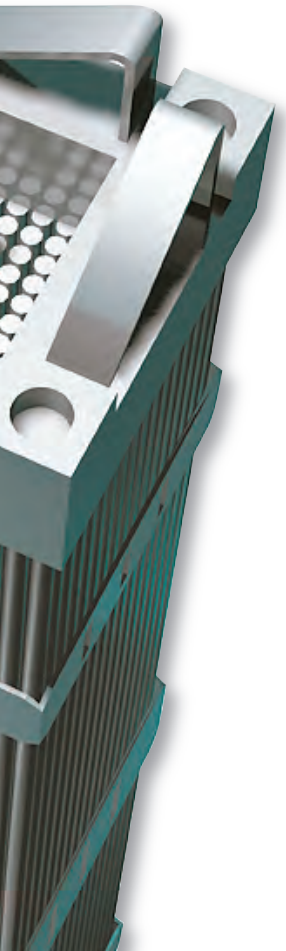


Uranium fuel: solid ceramic pellets.

The **uranium fuel** at nuclear power plants comes to the plant as small, **ceramic pellets** inserted and sealed into long, vertical metal alloy tubes or rods. Inside the **reactor vessel**, or the core, **nuclear fission** produces heat to create steam that powers electricity-producing generators. Nuclear fuel is a solid material enriched at a low level and cannot explode.

FACT:

One uranium fuel pellet provides as much energy as one ton of coal, 149 gallons of oil or 17,000 cubic feet of natural gas.



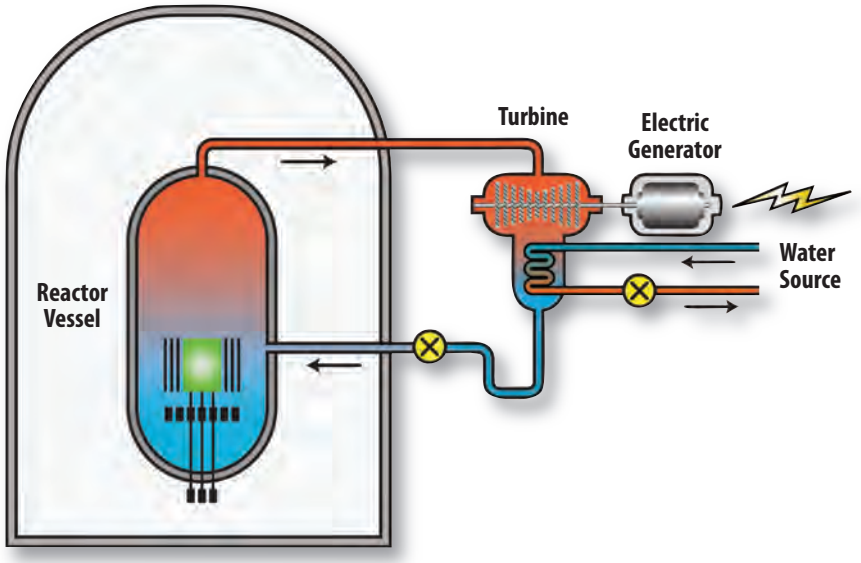
Types of nuclear power plants

There are two types of commercial nuclear power plants in the United States: boiling water reactors and pressurized water reactors. Ordinary water provides cooling for both types. Water is essential to the process that converts **fission energy** to **electrical energy**. Of the nation's 104 reactors, 69 are pressurized water reactors, while 35 are boiling water reactors.

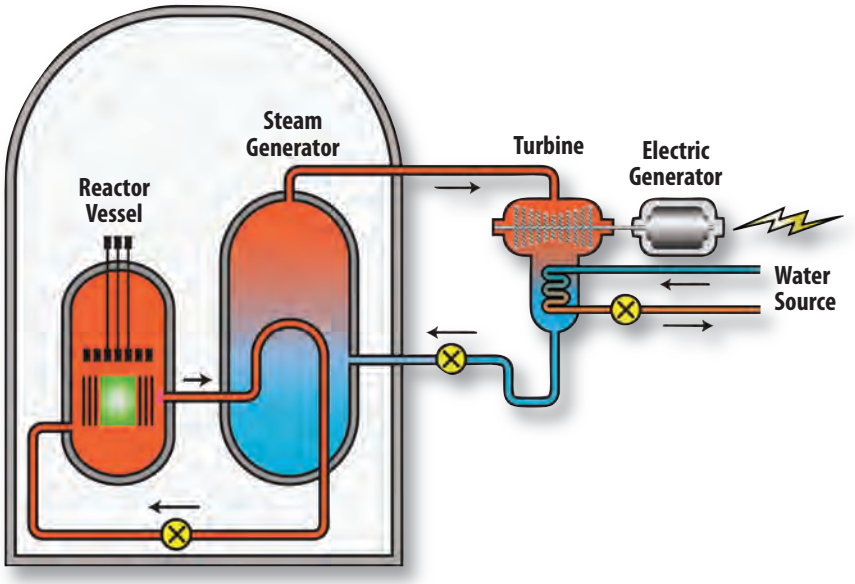
Boiling water reactors heat the water surrounding the nuclear fuel directly into steam in the **reactor vessel**. Pipes carry steam directly to the turbine, which drives the electric generator to produce electricity.

Pressurized water reactors heat the water surrounding the nuclear fuel in the **reactor vessel** but keep the water under pressure to prevent it from boiling. Pumps move the hot water from the reactor vessel to a **steam generator**. There, the water pumped from the reactor heats a second, separate supply of water, which boils to make steam. The steam spins the turbine, which drives the generator that produces electricity.

Boiling Water Reactor



Pressurized Water Reactor



How Nuclear Fuel Is Made

FACT:

Uranium must undergo four processing steps to convert it from an ore to solid ceramic fuel pellets: mining and milling, conversion, enrichment, and fabrication.

Uranium miners use several techniques: surface, underground and in-situ leach mining.

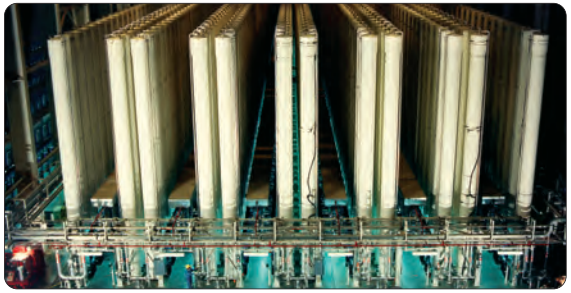
In-situ leach mining uses liquids to recover minerals from the underground ore. Uranium also can be a byproduct of other mineral processing operations. After mining, material is milled and processed to create **uranium oxide**, or "**yellowcake**." Most uranium mining in the United States uses the in-situ process, whereas Canada and Australia primarily use the surface and underground approaches.

Yellowcake requires further processing before its use as a fuel.

In the next step, the uranium oxide goes to a conversion plant, which removes impurities and chemically converts the material to **uranium hexafluoride**. The compound is heated to become a gas and is loaded into cylinders, where it cools and condenses into a solid. One of the world's five commercial conversion plants is in Metropolis, Ill. The others are in Canada, France, Russia and the United Kingdom.

Mining and Milling

Conversion of Yellowcake



Enrichment Centrifuges

FACT:

Uranium fuel pellets are loaded into fuel rods. When grouped, they form fuel assemblies for insertion into the reactor.

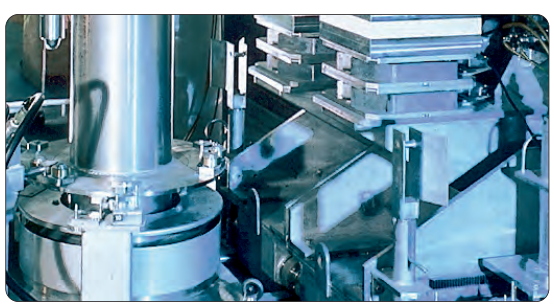
Utilities can buy uranium and have it enriched, or they can buy uranium already enriched.

Uranium hexafluoride contains two different forms, or **isotopes**, of uranium; one (U-238) is heavier than the other (U-235). The lighter U-235 is "fissionable" and typically makes up less than 1 percent of uranium by weight, while U-238 accounts for more than 99 percent. To make uranium usable as a fuel, its U-235 content must increase to 3 percent to 5 percent by weight through a process called **enrichment**.

The U.S.-Russia **"Megatons to Megawatts"** program downblends uranium from the Russian weapons program into commercial reactor fuel used in U.S. plants.

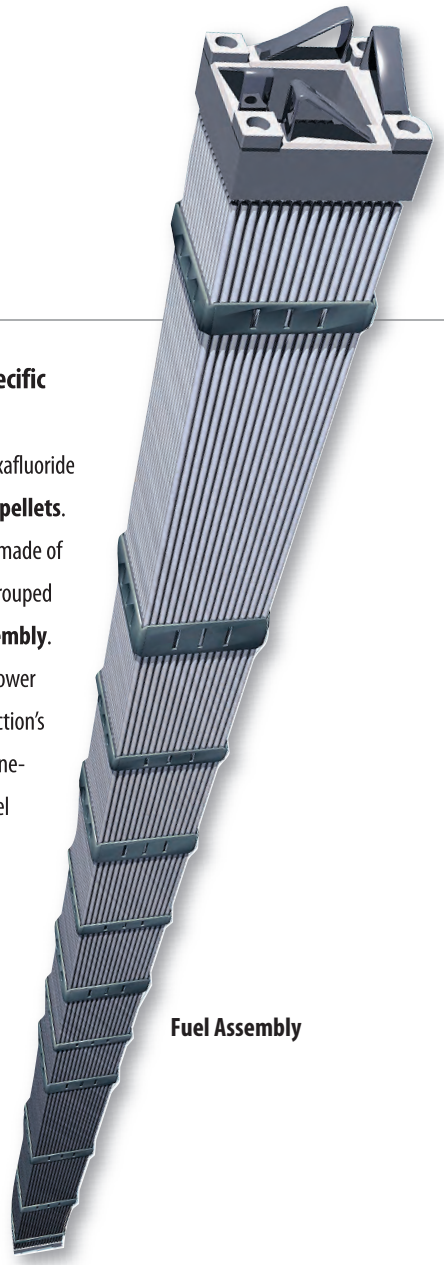
Fuel assemblies are designed to meet the specific requirements of each nuclear reactor.

After enrichment, a fuel fabricator converts uranium hexafluoride into **uranium dioxide** powder and presses it into **fuel pellets**. The fabricator loads the ceramic pellets into long tubes made of a noncorrosive material, usually zirconium alloy. Once grouped together into a bundle, these fuel rods form a **fuel assembly**. Multiple assemblies, which average 14 feet in length, power a reactor for 36 to 54 months, after which the chain reaction's efficiency begins to decrease. Operators replace about one-quarter to one-third of the fuel assemblies with new fuel every 18 to 24 months.



Fuel Fabrication

Fuel Pellet (Actual Size)



Fuel Assembly

Managing Used Nuclear Fuel

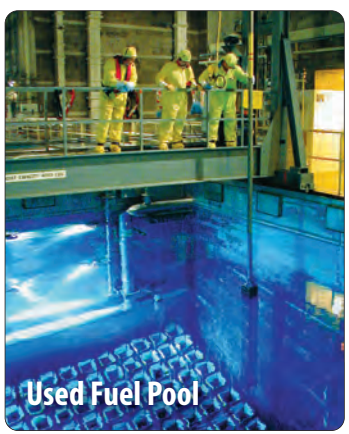
FACT:

Used nuclear fuel is a solid material safely stored at nuclear plant sites. This is one part of an integrated used fuel management system.

Nuclear power plants store used fuel safely and securely on site in steel and concrete vaults.

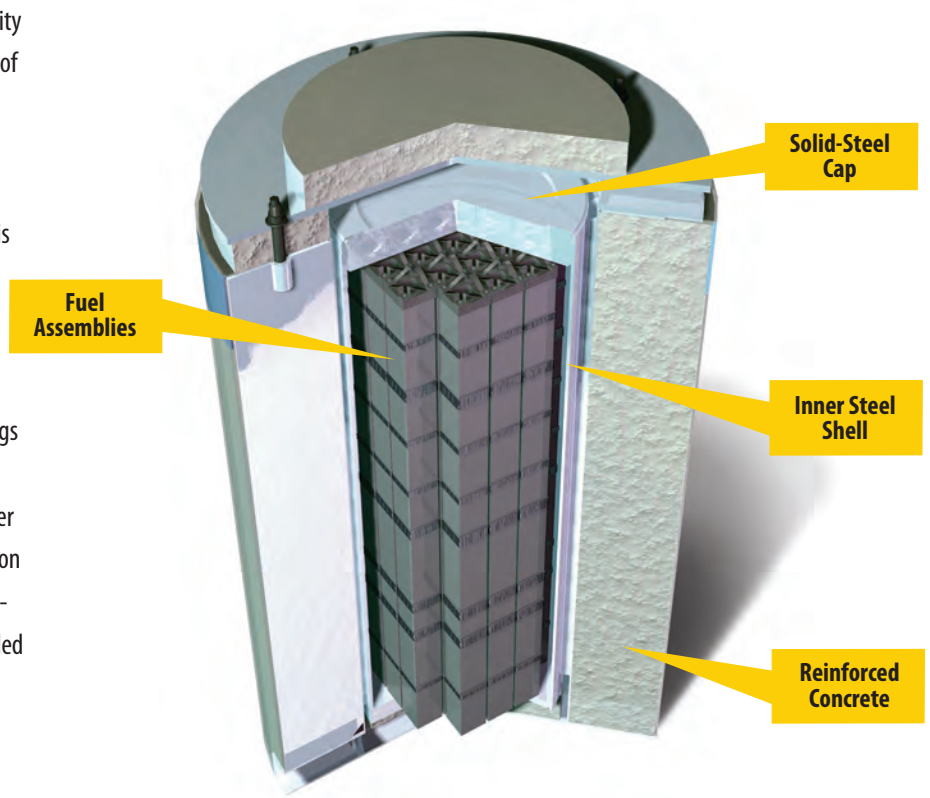
Nuclear power plants produce relatively little waste.

A typical large nuclear power plant produces enough electricity for more than 750,000 homes but only about 20 metric tons of **used uranium fuel** each year. In terms of volume, that is roughly equivalent to the cargo area of a small truck. Commercial reactors in the United States together produce about 2,000 metric tons of used fuel annually. The used fuel is highly radioactive and must be contained safely.



Used fuel at nuclear plant sites is managed securely in special buildings that house the fuel in steel-lined, concrete pools filled with water. After the used fuel cools, it can be stored on plant property in huge steel or steel-lined concrete containers. This is called **dry cask storage**.

A Typical Dry Storage Container



FACT:

The nuclear industry has safely transported more than 3,000 shipments of used nuclear fuel over the past 40 years.

Used fuel containers will travel by trains, trucks and barges to a disposal facility.

Robust containers keep their contents safe.

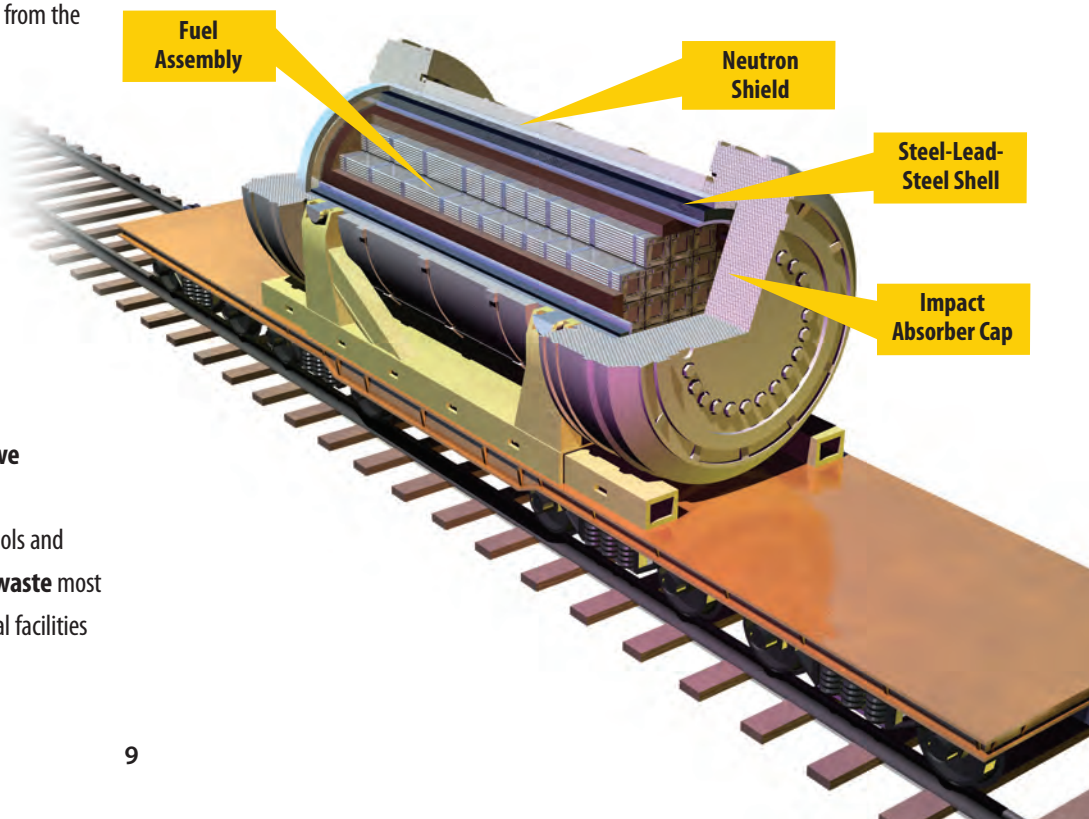
The industry has an **exemplary safety record** for used nuclear fuel transportation. These shipments have covered 1.7 million miles with no injuries, fatalities or environmental damage resulting from the radioactivity of the cargo.

When the Yucca Mountain repository opens, shippers will transport fuel for disposal in special containers by rail, truck and possibly barge. The U.S. Nuclear Regulatory Commission and U.S. Department of Energy's national laboratories have subjected **shipping containers** to intense crash and fire tests to ensure safe shipments even under extreme conditions.

Nuclear power plants manage byproducts that have low levels of radioactivity.

This waste includes such things as protective clothing, tools and equipment. Shippers transport **low-level radioactive waste** most often by truck to one of several federally licensed disposal facilities located throughout the country.

Train Container and Transport Car



Yucca Mountain and Advanced Fuel-Cycle Technologies

FACT:

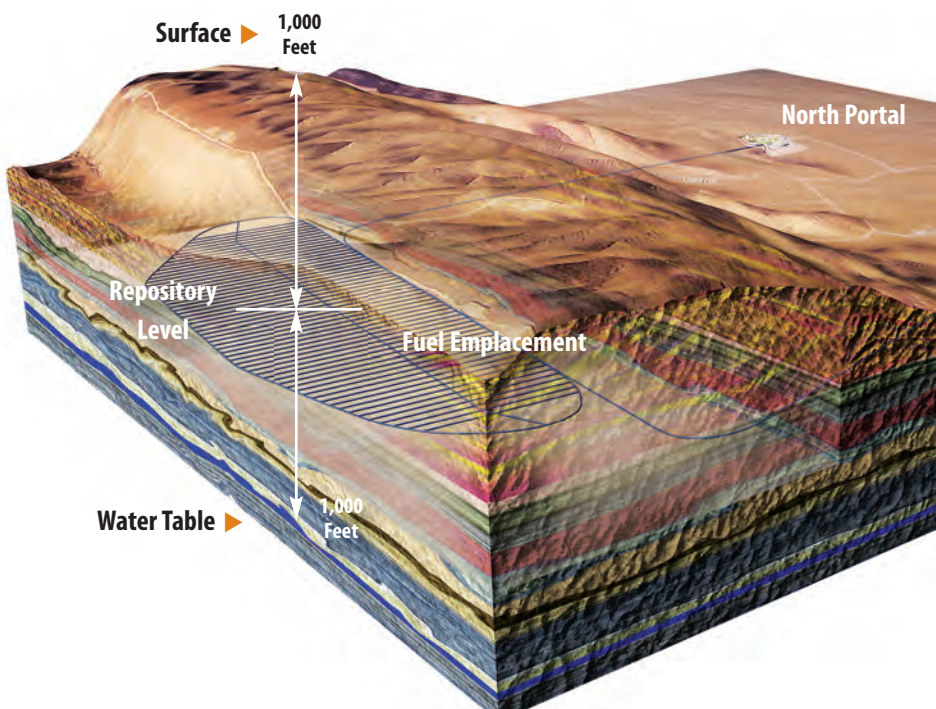
The U.S. government has a legal obligation to manage reactor fuel and plans to dispose of this material at a specially designed repository at Yucca Mountain, Nev.

Used nuclear fuel is managed through an integrated program.

Deep geologic disposal is the best method of managing used reactor fuel absent a recycling program, according to the National Academy of Sciences. A long-term objective for managing used fuel or byproducts from recycling is the construction of a **repository** 1,000 feet under Yucca Mountain, Nev. The highest level of public safety and environmental protection would be provided by an integrated program that includes the development of recycling technologies, temporary storage of used fuel, and its safe packaging and transportation before permanent disposal.

The government will build an underground repository for permanent disposal.

Scientists began studying Yucca Mountain, Nev., in the early 1980s as a possible site for a repository for used fuel, as well as high-level radioactive waste from the nation's defense programs. The president and Congress **approved the site** in 2002. DOE will build and operate the repository if the NRC approves the license application. Thirteen other nations plan to dispose of used nuclear fuel in underground repositories.



FACT:

Advanced technologies for recycling nuclear fuel could reuse 90 percent of the energy in a fuel rod and reduce the volume and toxicity of the waste that requires disposal.

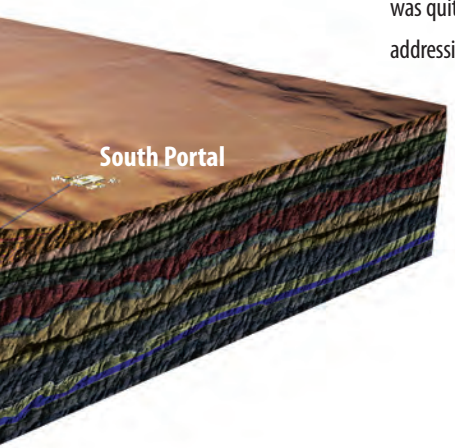
Used fuel would be readied at Yucca Mountain, Nev., surface facilities for emplacement in the repository.

The United States currently does not recycle reactor fuel.

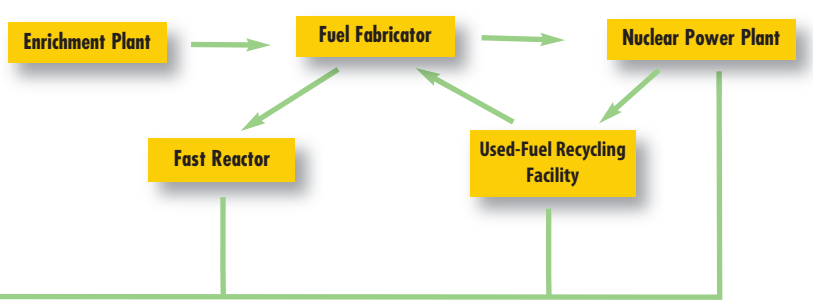
The U.S. government decided to stop **recycling used fuel** in the 1970s because of economic and proliferation concerns. Although technology makes it possible to **recycle** and **reuse** uranium and plutonium from used nuclear fuel, the separated plutonium raised proliferation concerns. This process also was quite expensive. Advanced recycling technologies hold the promise of addressing both these issues.

Nuclear energy's resurgence has renewed interest in advanced fuel-cycle technologies.

The expected expansion of nuclear energy has prompted a new initiative to develop and commercialize **advanced fuel-cycle technologies**. Development of these fuel-cycle technologies will take several decades and billions of dollars to complete. Although the nuclear energy industry supports such research and development, no technology will preclude the need for a federal repository.



Advanced Nuclear Fuel Cycle



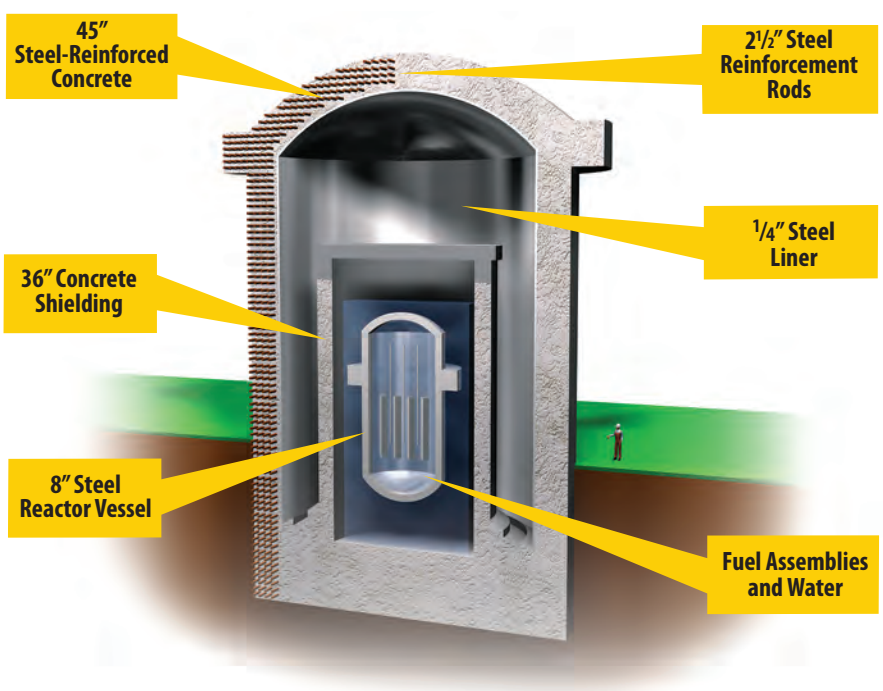
Safety Is Paramount in Nuclear Plant Operations

FACT:

Nuclear power plants are designed and operated safely, with multiple back-up safety systems, including automatic shutdowns.

Ongoing and on-the-job training for reactor operators and other key personnel has contributed to the nuclear energy industry's excellent safety record.

U.S.-Style Nuclear Reactor—Defense in Depth



The nation's nuclear power plants are among the safest and most secure industrial facilities in the United States.

Automated, multiple safety systems, the industry's commitment to comprehensive safety procedures and stringent federal regulation keep nuclear power plants and their communities safe.

The NRC, an independent federal agency, strictly regulates the commercial and institutional uses of nuclear energy, including nuclear power plants. The agency regulates plant performance according to three strategic areas: **reactor safety, radiation safety and security**. Independent NRC inspectors at each plant provide oversight of plant operation, maintenance, equipment replacement and training. The NRC posts all performance results on its Web site *(www.nrc.gov)*.

The nuclear energy industry has an impeccable safety record.

Quality plant construction, continuous **preventive maintenance** and ongoing **reactor operator training** all have contributed to the nuclear energy industry's excellent safety record. Levels of safety in the nuclear energy industry exceed those of the overall electricity industry and of the manufacturing sector.

FACT:

Accidents at Three Mile Island and Chernobyl, though serious events, led to significant improvements in nuclear plant safety.

All commercial nuclear plants have emergency response procedures in the event of an accident or security event.

These procedures are evaluated regularly during extensive drills involving plant personnel and local police, fire and emergency management organizations. NRC and Federal Emergency Management Agency expert teams evaluate some of these drills.

Nuclear plant staff and local emergency responders drill together to ensure close coordination.

Background on the accident at Three Mile Island

The accident at Three Mile Island (TMI) in 1979 was caused by a combination of equipment failure and the inability of plant operators to understand the reactor's condition at certain times during the event. A gradual loss of cooling water to the reactor's heat-producing core led to partial melting of the fuel rod steel cladding and the uranium fuel and the controlled release of a small amount of radioactive material. The TMI accident caused no injuries or deaths. Also, experts concluded that the amount of radiation released into the atmosphere was too small to result in discernible health effects to residents in the vicinity of the plant. At least 12 epidemiological studies conducted since 1981 have confirmed this fact.

Background on the accident at Chernobyl

The 1986 accident at the Chernobyl nuclear power plant in Ukraine is the only accident in the history of commercial nuclear power to cause on-site fatalities from radiation. It was the product of a severely flawed Soviet-era reactor design combined with disregard of operating protocols. A Chernobyl-type reactor would not meet U.S. safety standards and could not be licensed in the United States.

Building New Nuclear Plants

FACT:

Energy companies and consortia are pursuing plans to build as many as 30 new nuclear power plants to help meet projected increases in U.S. electricity demand.

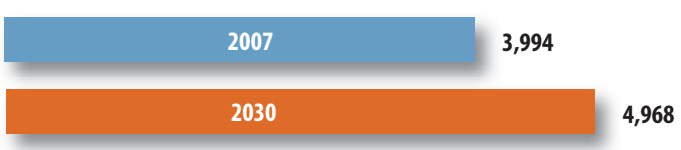
About 30 nuclear power plants are under construction around the world.

The United States will need nearly 300 new power plants by 2030.

The U.S. Department of Energy forecasts the United States will need about 260,000 megawatts of new electric generating capacity by 2030, equivalent to 260 new large power plants. This rising electricity demand, along with concerns about greenhouse gases and pollution, make new nuclear plants vital to our **energy mix**. Energy companies are developing **license applications** to build as many as 30 new commercial reactors in the United States. Several companies already have submitted applications for new reactors that the NRC is reviewing under its new licensing process.

U.S. Electricity Demand Will Increase 25 Percent by 2030

(in billion kilowatt-hours)



Source: Energy Information Administration

The federal government is planning for future electricity needs.

The Energy Department and the industry are participating in **Nuclear Power 2010**, a jointly funded program that has two major goals. The first is to test the NRC's new licensing process for nuclear power plants. The second is to complete first-of-a-kind design and engineering on two reactor designs so electric utilities can obtain the firm cost estimates they need for decision-making purposes.

U.S. companies are rebuilding infrastructure for new reactors.

Suppliers expect they can meet the needs of the first few new reactors. They have launched new initiatives, however, to develop the **manufacturing base** for new plants and to ensure the industry has the right construction management, engineering expertise and skilled labor needed for the future. New-plant construction will provide thousands of **additional jobs**. Building a new nuclear plant will create 1,400 to 1,800 jobs during construction, with peak employment as high as 2,400 jobs.

The industry is training and recruiting the nuclear work force of the future.

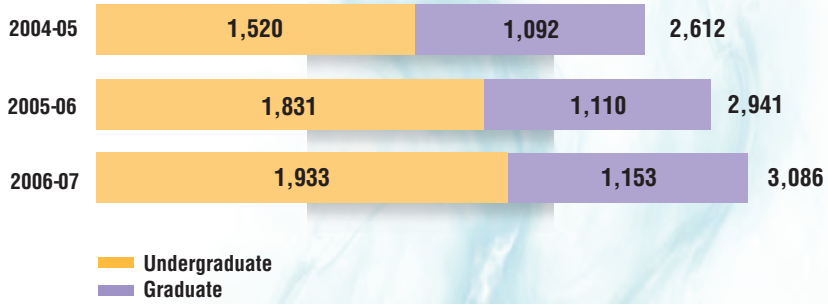
Because 35 percent of workers in the nuclear energy industry will be eligible to retire within five years, the industry is focusing on staffing and recruitment issues to retain a **high-quality** work force. The industry has intensified its recruiting efforts to address ethnic diversity issues, expand opportunities for women and attract talented employees needed in specific professions, such as **nuclear engineering** and **health physics**.

Nuclear energy's expansion in the United States will require thousands of new workers.

Industry efforts to increase the work force have begun to show results.

The number of students enrolled in four-year nuclear engineering programs increased to 1,800 in 2006 from a low of about 500 in 1998. The industry also has partnered with local technical and community colleges and organized labor to develop **technicians** and **craft personnel**. But the industry still faces a critical shortage of skilled workers to build the next generation of nuclear plants.

Nuclear Engineering Enrollment



Source: U.S. Department of Energy

Economic Benefits

FACT:

Nuclear power plants create hundreds of high-paying jobs at the plants and in the surrounding communities.

The Three Mile Island nuclear plant purchased a new fire truck for Londonderry Township, Pa.

Operation of a U.S. nuclear plant generates 400 to 700 permanent jobs.

The 400 to 700 permanent jobs at a nuclear plant pay 36 percent more than average salaries in the local area. The plant also creates an equivalent number of additional jobs in the **local area** to provide the goods and services necessary to support the nuclear plant work force.

Nuclear plants provide economic benefits to their local communities.

Each year, the average nuclear plant generates approximately $430 million in sales of goods and services in the local community and nearly $40 million in total labor income. These figures include both **direct** and **secondary effects**. The direct effects reflect the plant's expenditures for goods, services and labor. The secondary effects include subsequent spending attributable to the presence of the plant and its employees as plant expenditures filter through the local economy (such as restaurants and shops buying goods and hiring employees). The average nuclear plant generates total state and local **tax revenue** of almost $20 million each year. These tax dollars benefit schools, roads and other state and local infrastructure. Each nuclear plant generates federal tax payments of roughly $75 million each year.

Additional jobs are created to provide goods and services like grocery stores, dry cleaners, car dealers, etc.

FACT:

Nuclear power has a lower production cost than coal or natural gas, so it helps reduce the price of electricity for consumers.

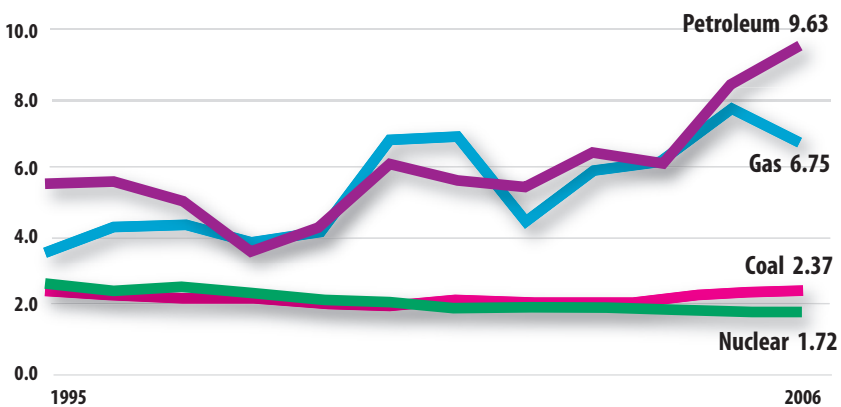
Nuclear energy provides reliable electricity around the clock to power our digital world.

Nuclear power is the lowest-cost producer of baseload electricity.

Average **electricity production costs** at nuclear power plants have declined more than 30 percent in the past 10 years to an average of 1.7 cents per kilowatt-hour. This includes the costs of operating and maintaining the plant, purchasing nuclear fuel, and managing used fuel. Electricity generated from nuclear power also has tremendous forward **price stability** because only about one-quarter of production costs are fuel costs. Fuel accounts for 80 percent to 90 percent of the cost of electricity produced by fossil fuel-fired generation, making it highly susceptible to fluctuations in coal and gas prices.

U.S. Electricity Production Costs

(in 2006 cents per kilowatt-hour)



Source: Global Energy Decisions

Nuclear Energy Key Statistics

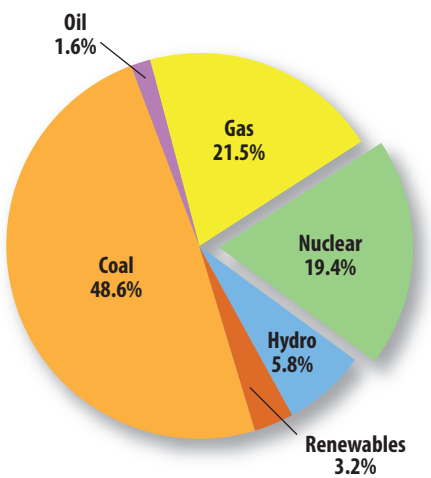
FACT:

Improvements in nuclear power plant efficiency since 1990 have raised total electricity output by an amount equal to building 29 new reactors.

The United States has the world's largest commercial nuclear energy program.

Each year, America's 104 nuclear power plants **alone** produce more electricity than does any single country from **all generating sources** except China, Japan and Russia. Efficiency gains have enabled nuclear plants to increase output by 40 percent since 1990 without building any new reactors. Because nuclear plants do not produce greenhouse gases, the amount of carbon dioxide emissions they prevent is larger than all other electricity sources combined. As a result of these factors, public opinion surveys show a **steady increase** in support for nuclear energy. The following graphs illustrate nuclear energy's increasing value to consumers and importance to our nation's energy supply.

U.S. Electricity Generation by Fuel Type



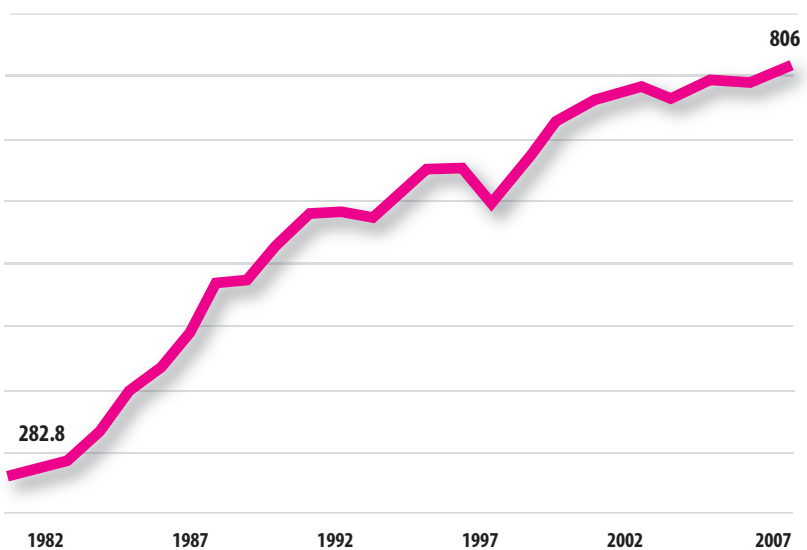
Source: Global Energy Decisions/ Energy Information Administration

FACT:

In seven states, nuclear energy makes up the largest percentage of electricity production: These include Vermont (75%), New Jersey (53%), South Carolina (52%), Illinois (49%), Connecticut (48%), New Hampshire (42%) and New York (30%).

Nuclear Energy Output Sets Production Record in 2007

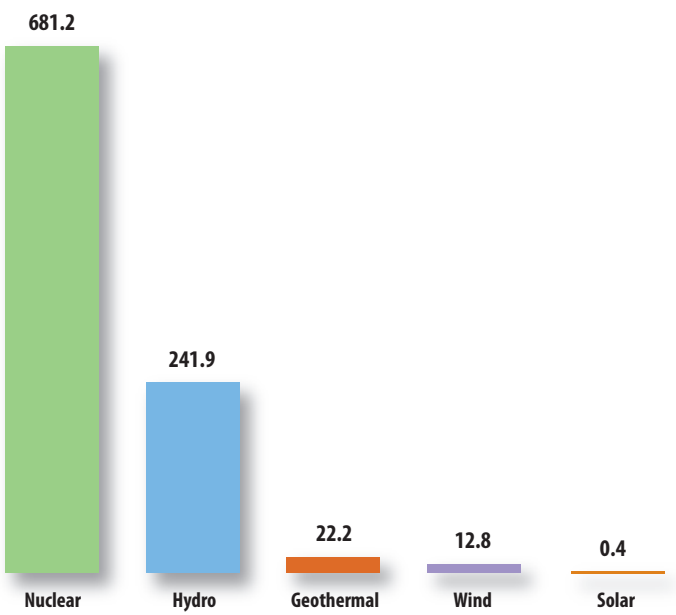
(in billions of kilowatt-hours)



Source: Global Energy Decisions/ Energy Information Administration

Emissions Avoided by U.S. Electric Power Industry

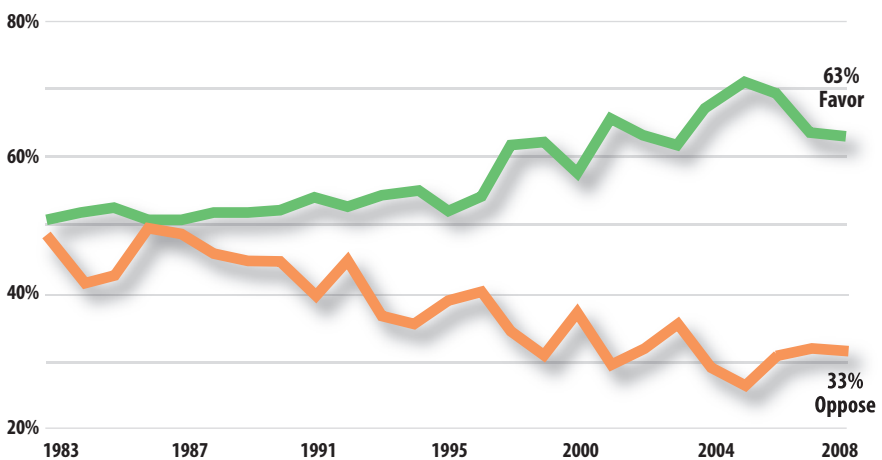
(in million metric tons of CO_2)



Source: Environmental Protection Agency/ Energy Information Administration

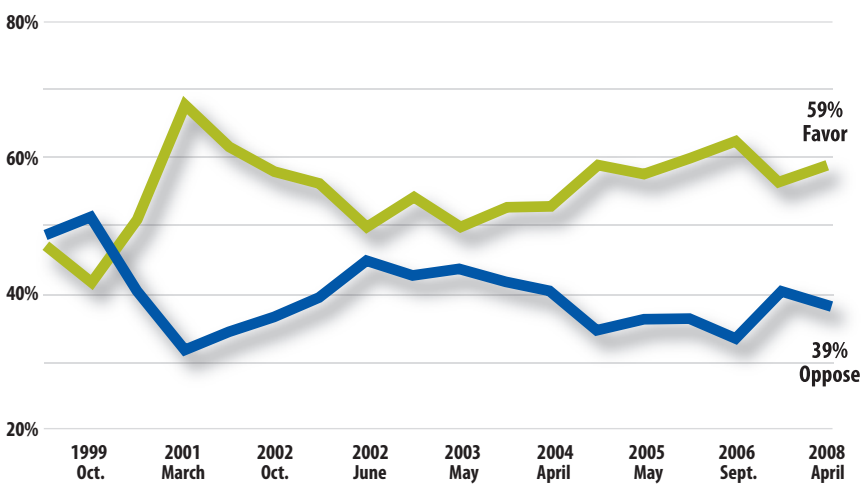
Nuclear Energy Key Statistics

Steady Growth in Public Support for Nuclear Energy



Source: Bisconti Research Inc.

Growing Support for Building More Nuclear Power Plants



Source: Bisconti Research Inc.

The Nuclear Energy Institute is an industry policy organization that fosters the beneficial uses of nuclear technologies worldwide.

The Institute's members include companies that operate commercial nuclear power plants, their suppliers and labor unions, as well as leading universities, research laboratories, radiopharmaceutical and radioisotope manufacturers, and others.

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